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Arnaud Lenoble, Alain Queffelec, Dominique Bonnissent, Christian Stouvenot

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INDICE

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ROCK ART TAPHONOMY IN LESSER ANTILLES: STUDY OF WALL WEATHERING AND ENGRAVINGS PRESERVATION IN TWO PRECOLUMBIAN CAVES ON MARIE-GALANTE ISLAND.

Arnaud Lenoble (arnaud.lenoble@u-bordeaux.fr; alain.queffelec@u-bordeaux.fr)
Alain Queffelec, PACEA – UMR CNRS 5199,
Université de Bordeaux, 33 615 Pessac Cedex, France

Dominique Bonnissent (dominique.bonissent@inrap.fr)
Inrap, Centre archéologique de Guadeloupe, 97 113 Gourbeyre, Guadeloupe (F.W.I.), ARCHAM - UMR CNRS 8096

Christian Stouvenot (christian.stouvenot@culture.gouv.fr)
DAC Guadeloupe, 97 100 Basse-Terre, Guadeloupe (F.W.I.), ARCHAM - UMR CNRS 8096

SUMMARY

The islands of Guadeloupe deliver some caves and rock shelters occupied in precolumbian times, including rare engraved caves whose age of occupation remains unclear and some burial caves used in the Late Ceramic Age. Question arises whether the absence of engravings in these latter sites reflects an archaeological reality or, in contrast, is linked to poor conditions for the preservation of cave art.

Here we present a study carried out to determine the conditions of conservation of precolumbian rock art. This study was conducted in two sites of Marie-Galante, the cave Blanchard, without obvious engravings but with a funeral dimension, and the Morne Rita cave, rich in engravings. This work includes a series of hygrothermal measurements, the determination of authigenic minerals, and the study of both cave sediments.

Two types of cavities can be opposed in terms of micro-climate pattern and transformation of the walls. Caves acting as trap cold air, like Morne Rita cave, have a high humidity which causes a light corrosion of the rock and mineral crust formation. Engravings modification proceeds mainly by their recovery by mineralization and the petroglyphs are relatively well preserved. In contrast, sites acting as warm air traps, like Blanchard cave, are characterized by an unstable air mass that promotes

the entrance of drying air rich in salt-sprays, especially when sites are not far from the coast, which is the most frequent case in the Lesser Antilles. As a result, rock is exposed to salt weathering, and walls retreat caused by this phenomenon has been estimated in the order of a millimeter per century. This rate is sufficient to result in the disappearance of engravings that could exist in such sites. The walls of the Blanchard cave were examined in detail to find any traces of weathered petroglyphs, and we present here a wall morphology that could be explained by this hypothesis.

This study highlights the control of site microclimatic pattern on the preservation of petroglyphs and concludes, therefore, on the existence of a bias in the distribution of rock caves in the Lesser Antilles where decorated caves were probably many more that which is currently found. The implications of this result on precolumbian cave occupation models are finally discussed.

Keywords: rock art, taphnomy, Lesser Antilles

RÉSUMÉ

Les îles de Guadeloupe livrent quelques grottes et abris-sous-roches occupés à l'époque précolombienne, parmi lesquels de rares cavités ornées dont l'âge reste à préciser et quelques grottes funéraires utilisées au Néoindien récent. Question se pose de savoir si l'absence de gravures dans ces derniers sites est le reflet de choix culturels ou, à l'inverse, est liée à de mauvaises conditions de préservation des œuvres d'art.

Nous présentons ici une étude du fonctionnement naturel des cavités qui permet de déterminer les conditions de conservation de l'art rupestre. Cette étude est menée dans deux cavités de Marie-Galante, la grotte Blanchard, à dimension funéraire et exempte de gravures évidentes, et la grotte du Morne Rita, riche en figures rupestres. Le travail réalisé inclut une série de mesures hygrothermiques, une description des sédiments et une détermination des minéraux authigènes contenus dans les cavités.

Il en ressort que deux types de cavités peuvent être opposés du point de vue du fonctionnement micro-climatique et de l'évolution des parois. Les grottes fonctionnant en piège à air froid, comme celle du Morne Rita, présentent une humidité élevée qui induit une corrosion modérée de la roche et la formation de croûtes minérales. La dégradation des motifs rupestres tient surtout à leur recouvrement par les minéralisations et, finalement, les pétroglyphes y sont relativement bien conservés. A l'inverse, les pièges à air chaud, comme la Grotte Blanchard, se caractérisent par une masse d'air instable qui favorise les courants d'air asséchant et la pénétration d'embruns, en particulier lorsque les sites sont peu éloignés du littoral, ce qui est un cas fréquent dans les Petites Antilles. Il en résulte une désagrégation du rocher par haloclastie. Le recul des parois provoqué par cette désagrégation peut être estimé de l'ordre du mm par siècle. Ce taux est suffisant pour conduire à la disparition de gravures qui auraient pu y être faites. Les parois de la Grotte Blanchard ont été examinées en détail de façon à y rechercher d'éventuelles traces de gravures en partie effacées. Un sérieux candidat a été reconnu que nous présentons ici.

Cette étude fait ressortir le contrôle du fonctionnement microclimatique des sites sur la préservation des pétroglyphes et conclut, par conséquent, à l'existence d'un biais dans la représentation des grottes rupestres des Petites Antilles qui ont pu être en plus grand nombre que ce qui est actuellement constaté. Les implications de ce résultat sur les modèles anthropologiques de l'occupation des grottes sont discutées.

Mots-clés: art pariétal, taphonomie des parois, Petites Antilles

RESUMEN

Las islas de Guadalupe revelan unas grutas y abrigos rocosos ocupados en la época precolombina. Entre ellos, encontramos escasas cavidades gravadas cuya edad queda por determinar y una serie de grutas funerarias de la Tardia Era Cerámica. ¿Refleja esta ausencia de grabados en estos últimos parajes, una realidad arqueológica o, al contrario, se vincula con malas condiciones de preservación de las obras de arte?
Aquí presentamos un estudio del funcionamiento natural de las cavidades que permite determinar las condiciones de conservación del arte rupestre. Este estudio fue llevado a cabo dentro de dos cavidades de la isla Marie-Galante: la gruta funeraria de Blanchard, exenta de grabados evidentes y la gruta adornada del Morne Rita. El trabajo realizado incluye una serie de medidas higrotérmicas, una determinación de los minerales antígenos y una descripción de los sedimentos hallados dentro de las cavidades.

Resulta que se oponen dos tipos de cavidades del punto de vista del funcionamiento micro-climático y de la evolución de las paredes. Las grutas que funcionan como trampas de aire frío, como la del Morne Rita, presentan una humedad elevada que engendra una corrosión de la roca y la formación de cortezas minerales. Es, sobre todo, el recubrimiento de los grabados por las mineralizaciones que induce la degradación y, al fin y al cabo, los petroglifos quedan relativamente bien conservados. Opuestamente, las trampas de aire caliente, como la gruta Blanchard, se caracterizan por una masa de aire inestable que favorece las corrientes de aire seco y la penetración de salpicaduras, en particular cuando los parajes se aproximan al litoral, cosa muy frecuente en las Antillas Menores. Así se produce una disgregación de la roca por haloclastia. El retroceso de las paredes, provocado por la disgregación, ha sido estimado del orden del milímetro al siglo. Esta tasa es suficiente para que desaparezcan los grabados que podrían haber sido hechos. Las paredes de la gruta Blanchard han sido examinadas en detalle, para buscar posibles trazas de grabados en parte borrados. Un candidato serio fue evidenciado y aquí lo presentamos.

Este estudio da a entender el control del funcionamiento microclimático de los parajes sobre la preservación de los petroglifos y concluye, por consiguiente, con la existencia de una alternativa en la preservación de las grutas rupestres de las Antillas Menores, que han podido ser más numerosas que lo que hoy constatamos. Son discutidas las implicaciones de aquel resultado en los modelos antropológicos de la ocupación de las grutas.

Like all sciences studying past, archeology relies on preserved remains of ancient times. As a consequence, archeology constantly faces the challenge engendered by the alteration or non-preservation of artifacts over time. The natural trend to degradation of human-generated products through time raises the question of representativeness of the remains collected. Studies on this topic have become an integral part of the archaeological approaches, falling under the denomination of archaeological taphonomy (Villa 2004).

If the alteration or degradation of artifacts is well suited for such studies, the non-preservation of archaeological remains is much more difficult to tackle, facing with what seems to be an insurmountable obstacle: how is it possible to study what no longer exists?

It is however possible to gain information even in the absence of human activity vestige. Two approaches can complement each other here. The first approach is the study of the environmental context of sites, namely the nature and importance of physicochemical processes that could lead to the disappearance of archaeological remains. The second approach is an assessment of the archaeological potential, by determining the types of human activities that could have occurred on a site. This assessment may rely on indirect information like an attractive topographic context or the presence on or near the site of remains that may be linked to the activity that is attempted to be highlighted.

In the Caribbean, such a situation is frequently illustrated by the case of a lack of shells and faunal remains on sites on which the interpretation of a village is quite obvious because of archaeological evidence like middens and postholes, the geological context (i.e. soil acidity) explaining the non-preservation of the bones and shells. A taphonomic perspective can be achieved as an intra-site study, but also at an inter-site scale. The question that then arises is: what does the absence of any recording of an activity related to a particular environment means, when this environment is not conducive to the preservation of the remains resulting from these activities? The case study presented here develops an approach designed to collect archaeological information even in the absence of evidence. It is applied to caves of Guadeloupe, which were investigated by the way of a multidisciplinary program from 2010 to 2013 (Lenoble et al. 2014).

This program provided an opportunity to reassess the archaeological occupation of caves on Guadeloupe Islands, and has produced several results (Grouard et al. 2014), the main ones being:

1. Many caves with indications of a precolumbian occupation exist in Guadeloupe. Thirty-five are currently listed on throughout the archipelago;
2. Radiometric dating and cultural attributions of ceramics sherds indicates that most of caves are used during the Late Ceramic Age,

INDICE

3. Several sites correspond to burial caves, like the caves Cadet 2 and Blanchard, in Marie-Galante, or Voûte à Pin in la Désirade.

These results contradict the assumption that the occupation of caves in the Lesser Antilles is uncommon (Rouse 1992), or concerns only a few ceremonial caves in the northern Islands as a result of Taino influences (e.g. Crock 2005; Petersen et al. 2005). These results support the opposite hypothesis that ceremonial or funeral activities in caves are a common feature in all the Caribbean, bringing together in a common historical development and/or social organization the Troumassoid groups of the Lesser Antilles and the pre-Taino societies of the Greater Antilles.

However, Amerindian caves in Guadeloupe differ in one respect from those of the Greater Antilles: rock art sites are rare. Indeed, despite an intensive survey, no new rock art cave was discovered. So far, only two caves with petroglyphs are known on the Guadeloupe Islands: the Morne Rita cave in Marie-Galante (Slozinski and Slozinski 1983; Dubellar 1995), and the Patate Rockshelter in Grande-Terre (Stouvenot and Richard 2005).

This low number of petroglyphs caves raises the question of a cultural specificity in Guadeloupe or, at a larger scale, in the Lesser Antilles, in comparison of the Greater Antilles where many rock art caves are known (e.g. Dubelaar 1994; Atkinson 2001; Miner-Sola 2013).

We consider here an alternative hypothesis, called taphonomic hypothesis. This hypothesis can be formulated as follows: the lack of rock art caves in Lesser Antilles results from the vanishing of Amerindian engravings and paintings in relation with a physicochemical context that promotes rapid wall degradation.

In order to discuss this hypothesis, we rely on the geological work to describe the mode of natural wall cave transformation, that is to say the modes of rock transformation as well as the processes controlling these modifications.

SITES

Two precolumbian caves, located on the southeastern coast of Marie-Galante were selected for this study: the Blanchard cave and the Morne Rita cave (Figure 1).

Both caves open near the shoreline in fossil cliffs bordering the actual coastal plain. Morne Rita cave is a 20 meters-long site located one hundred meters from the sea while Blanchard cave is a 30 meters-long cave 200 meters from the shore (Figure 2). Both sites contain bones and a few precolumbian ceramic sherds. In Blanchard cave, test-pits revealed a precolumbian burial in the entrance (Stouvenot 2005), as well as a use of the deeper part of the site (Lenoble and Grouard

2008). Radiocarbon dating shows that this site was used around 1000 up to 1400 years A.D. Neither engravings nor paintings are found in this site.

Morne Rita cave is a rock art cave (Slozinsky and Slozinsky 1983; Dubelaar 1995). With more than one hundred petroglyphs, this cave is the richest of the Lesser Antilles. Ceramics elements have recently been studied by one of the present author (D. B.). They indicate a first Cedrosan Saladoid occupation followed by a transitional Troumassoid occupation (~800 – 1100 A.D.). Recent test pits also revealed burials within the cave (Fouéré 2013).

METHODS

The mode of natural cave wall transformation is assessed on the basis of the determination of site climatic pattern, salt water content, authigenic minerals and sedimentation processes.

Site climatic pattern has been investigated by measuring annual and daily hygrometry and temperature variations (Cigna 2004). Both caves were outfitted with iButton temperature/humidity loggers (http://www.ibuttonlink.com). The loggers were placed at several spots for recording entrance, intermediate and deep cave variations. Blanchard cave and Morne Rita cave were equipped with respectively 3 and 5 spots relative to their length. Furthermore, in Blanchard cave, thermal air stratification was studied *via* vertical profiles made of 3 or 4 loggers set at different heights on a same spot. High-resolution (1 minute step) and low-resolution (3 hours step) recordings allowed drawing the daily and annual climatic cycles of the caves. The measures were compared with outside climatic data from the nearest meteorological station.

Salt content of dripping water in the Morne Rita cave was characterized in January 2011 by collecting the water in 8 dripping points distributed among the cave. Conductivity was measured on-site with a field-conductivity meter and the ionic composition of the water was analyzed on lab by ion chromatography.

Minerals in both sites have been analyzed after sampling of the crusts on the walls and roof and of the sediment on the ground or in the wall cracks. Each sample was air dried, crushed and analyzed by x-ray powder diffraction. Diffractograms were treated through the EVA application software coupled with a JCPDS-ICDD mineral database in order to identify every single crystalline phase. Small-sized crystals were analyzed by Raman spectrometry. All minerals are named according to the international list of minerals (Nickel and Nichols 2009). On each site, sedimentation processes were determined by analyzing the sedimentological characteristics of the deposit observed on the test pit sections during archaeological fieldwork. These observations have been completed by examining thin sections of resin-indurated sediment with a petrographic microscope.

The taphonomic hypothesis is well illustrated by the contradicting interpretations that can be made of an enigmatic relief identified on a wall of Blanchard cave. This relief looks like a simple face engraving, a very common theme in the Amerindian rock art (Figure 3). Nonetheless, the lack of manufacturing traces such as grooves or peck marks would indicate that this morphology is simply the result of a differential alteration of the rock wall. This morphology should therefore be named a **pareidolia**, i.e. a natural morphology that a visual interpretation links to a clear and identifiable element, an Amerindian engraving in this case. This morphology could also represent a weathered petroglyph. In order to discuss this assumption, this enigmatic morphology has been compared with the engravings of the Morne Rita cave by performing a morphometric analysis. The analysis was conducted by comparing the measurements of seven parameters of a simple face engraving (Figure 4). Fourty-four simple faces of the Morne Rita cave have been selected for the comparison and the measurements of these engravings have been derived from the drawings of Gay and Reynaud (2008).

RESULTS

Microclimatic Patterns

Blanchard cave roof presents an ascending morphology towards the rear part of the cave. This determines the microclimatic pattern of the cave: the warm air accumulates during the day by thermal ascension. This provokes a slightly higher temperature in the cave than outside, as shown by annual recordings (Figure 5a).

In contrast, weak but rapid drop in outside temperature caused by the dusk or rain events affects the air mass generating air currents. This air movement is revealed in daily recordings by the loss of thermal stratification (Figure 5b).

These air currents play a key role for two reasons:

1. The cold air enters the cave, is warmed once in the cave, becoming under saturated in water, and thereby absorbs walls and ground humidity. This pattern explains the constant dryness of the cave;
2. Air current allows the salt mist that is common in a coastal setting to enter the cave, bringing salt onto the walls and the floor.

The microclimatic pattern of Morne Rita cave is quite different. It is characterized by low daily variations and insensitivity to climatic events (Figure 5a). This pattern is related to an entrance located above the main volume of the cave, what promotes the accumulation of cold air by gravity. The air temperature remains

lower than most daily temperature fluctuations and the air mass is then very stable, without air circulation. This cold air trap pattern leads to an annual mean temperature 2°C lower than the outer temperature (Figure 5b).

The cave humidity approaches full saturation all year long. This is due to the formation of the cave in a faulted zone, what induces the occurrence of numerous fractures, filled with clay, that release throughout the year the water stored in the epikarst.

Chemical Composition of Water Dripping

Dripping water in Morne Rita cave is salted. The cave opens, indeed, on a littoral windswept slope. Sea spray settles on the slope where it is washed into the soil by rain. Water salt concentration changes along the year. The measurements conducted in January 2011 show that, with values comprised between 8 and 30 mS/cm (24°C), this concentration can reach half the sea water value (53,7 mS/cm at 26°C). Cationic and anionic content measurements reveal water rich in sodium chloride and poor in carbonate, corroborating the marine origin of dissolved salts. Comparison with sea water reveals a dilution by 3 to 6 depending on ions, with the more soluble elements (potassium and sodium) being the less diluted (Table 1). This differential dilution reveals an evolution of the water. Calcite (CaCO3) and magnesite (MgCO3) may have precipitate and modified the chemical composition of the water before its infiltration into fissure infilling.

	Cations				Anions					
	Na	K	Mg	Ca	Cl	NO2	Br	NO3	SO4	HCO3
Morne Rita	3,302	0,148	0,228	0,114	4,832	0,022	0,012	0,012	0,552	0,100
Sea water	11,053	0,409	1,316	0,422	19,836	-	0,069	-	2,780	0,111
dilution	3,3	2,8	5,8	3,7	4,1	-	5,7	-	5,0	1,1

Authigenic Minerals

Several authigenic minerals have been identified in both caves, mainly belonging to the phosphate or evaporite mineral groups (Lenoble and Queffelec 2014). In this second group, most commons minerals are gypsum and halite.

Nevertheless, authigenic minerals occurring on both caves are different. Morne Rita walls and ceiling are coated with a gypsum crust (CaSO4) formed from the salt water dripping in the cave. Precipitation of this mineral fits well with the chemical water composition since gypsum is the next mineral in the evaporite minerals succession once calcite and magnesite (or dolomite) have crystallized.

No halite has been detected in x-ray diffractograms, and this is explained by the high solubility of this mineral as well as the high humidity in the cave that maintains sodium and chlorine in their ionic form.

On the contrary, the main mineral derived from sea spray in Blanchard cave is halite (NaCl). This salt is very abundant in the loose beige silt laying at the base of the cave walls. Under a microscope, this silty sediment appears to be formed by fine limestone fragments, indicating sediment produced by rock disaggregation. The occurrence of salt then demonstrates an alteration process by salt weathering. The process can be resumed as follows:

1. Salty mist introduced into the cave by air currents settles on the walls and infiltrates by capillarity into the rock voids;
2. Halite crystals formation in pores generates crystallization pressure of several tens of megapascals if no more, what far exceeds the limestone resistance (3 to 5 MPa, Bell 2004);
3. This salt-induced rock fragmentation produces a dust of fine broken grains accumulating on the ground of the cave.

Thus, in a same littoral setting, the two sites show two distinct patterns of mineral formation and wall modification: gypsum forms a crust that coats Morne Rita walls while halite induces a disaggregation of the walls by salt weathering in Blanchard cave.

Sedimentation

Test-pit sections shows that sediment accumulated in Morne Rita cave is a crudely stratified colluvium, which takes place within a detrital fan developed from the entrance of the cave. Radiocarbon datings on charcoal indicate that this colluvium is not older than a few thousands of years. The thickness of the deposit does not exceed a few tens of centimeters, indicating a low sedimentation rate. Gypsum is systematically observed in thin sections. The occurrence of authigenic gypsum in the whole colluvial deposit indicates that the mode of mineralization recognized at the present-day in the site have not changed significantly over the past millennia.

Blanchard cave infilling is more complex. Precolumbian artifacts are included in a superficial layer that overlies several meters of natural stratified deposit (Lenoble et al. 2011). This deposit mainly consists of beds of organic silt in which fossil bat guano is recognized. Metric to plurimetric lenses of limestone rubbles are interspersed in the fossil guano assumed to result from occasional events of roof

breakdown. A third sedimentary facies is observed in the upper part of the deposit. This facies correspond to a mineral beige silt similar to the sediment produced by salt weathering.

Several radiocarbon datings were obtained from organic silt, and the age/depth model of the natural deposit indicates that the beige silt facies developed about 5000 years ago, once the sea level stabilized at an elevation near its present-day elevation following the deglacial sea-level rise. The microfacies of fine limestone fragments and the occurrence of halite in this beige silt confirm that it was produced by the same process of salt weathering.

The presence of this single facies in the last millennia is interpreted as a change in mode of wall transformation once salt air can enter the cave as a consequence of a near-shore location.

Morphometric Analysis

The morphometric indices of the enigmatic morphology observed on the walls of the Blanchard cave and the Morne Rita engravings are plotted on graphs (Figure 6). As shown by this figure, the enigmatic morphology fits into the variability of the Morne Rita engravings, whatever the morphometric indices considered (spacing of the eyes, face width, etc.). This applies to the absolute dimensions of the components of the face (Figure 6a). This is also true for the ratios between the different components of the face. These ratios are represented by the regression lines established from Morne Rita engravings, and shown on Figure 6b. On graphs, the position of the enigmatic morphology near the regression lines thus shows that the analogy with the Morne Rita engravings also includes the petroglyph proportions.

DISCUSSION

The Enigmatic Morphology in Blanchard Cave: Weathered Petroglyph or Pareidolia?

Aside from rock art, archaeological contexts of Blanchard and Morne Rita caves are very similar. Among other things, both caves were occupied in the Late Ceramic Age, and the few number of archaeological remains found during excavations suggests that both caves were not used as habitat sites but rather as specialized sites (Grouard et al. 2014). However, their microclimatic and mineralization pattern are quite different. Morne Rita is a wet cave in which a gypsum crust covers the walls while Blanchard is a dry cave where wall modification is dominated by salt weathering (Figure 7).

The rate of wall recession in Blanchard cave can be estimated based on sedimentological data. The 30 cm-thick layer of sediment produced by salt weathering in the rear part of the cave accumulated for 5000 years, thus indicating a sedimentation rate of 6 mm per century. The wall recession rate can then be calculated by taking account of the ratio between the walls and ground surfaces, in one hand, and the volume change from rock to sediment that varies in relation to the porosity of the rock (Fine 1998), on the other hand. The resulting values are ranging between 1 and 2 mm per century, depending on the layer thickness that is considered, this layer being not perfectly constant. A value of 1 mm is then considered to be a conservative estimation of wall recession rate.

The wall modification patterns documented in both sites determines the preservation of rock art. Indeed, in Morne Rita cave, gypsum crust covers engravings and paintings, preserving them from corrosion. In contrast, in Blanchard cave, a recession rate of 1 mm per century leads to estimate that the walls retreat was ca. 1 cm during the millennium that follows the precolumbian occupation. As a consequence, petroglyphs which could have been made in the last cave would probably no longer exist.

This result lends credibility to the hypothesis that the enigmatic morphology observed in Blanchard cave is indeed a weathered petroglyph. Long-lasting features are then the relative positioning of the cupules figuring the eyes and the mouth and the circle delimiting the face. The morphological comparison shows that the enigmatic relief in Blanchard cave shares the size and morphology of Morne Rita engravings, upholding the interpretation of a weathered petroglyph. The absence of peck marks and the blurred character of the cupules of this enigmatic figure may also be resulting from the wall erosion. The location of this morphology is also consistent with the interpretation of a weathered engraving. It lies close to a light source formed by a roof collapse, few meters from the cave entrance. This sheltered place receives daylight, without being exposed to direct sunlight, what fits the pattern of single face engravings located in a enlightened location near cave entrances (Dubelaar 1995; Petersen et al. 2005; Roe 2009).

All these arguments make plausible the interpretation that face observed in the enigmatic morphology in the cave Blanchard isn't a pareidolia, but represents a weathered petroglyph.

So, even if the absence of peck marks or grooves doesn't allow demonstrating that the Blanchard cave is a rock art site, nor even less can be shown that the cave wasn't engraved in precolumbian time. In others words, the present-day absence of petroglyphs cannot be taken into account to conclude that the cave wasn't a ceremonial site as defined by Crock (2005) and Petersen (Petersen et al. 2005), namely a rock art site in which archaeological remains are present (ceramics, fauna, etc.).

The Blanchard Cave: a Unique Case?

The wall transformation pattern documented in Blanchard cave, characterized by a salt weathering induced wall recession, is likely to apply to other caves. This pattern causes the non-preservation of Amerindian rock art. So, the determination of caves falling within this pattern should allow for assessing the proportion of sites in which a rock art would no longer exist.

Several criteria can be derived from the Blanchard cave study to identify such caves:

1. A coastal setting inducing salt air. This applies to the caves located at a distance of less than a kilometer from the shore, whatever the topographic position of the site, i.e. plain, slope or plateau (Lenoble and Queffelec 2014);
2. A horizontal or ascending development of the cave which promotes the formation of air currents as well as a dry atmosphere;
3. The occurrence of a loose beige silt on the ground showing a disaggregation of the rock;
4. A salty taste of this sediment, indicative of halite.

These four criteria can be assessed during a site survey without carrying out any site instrumentation or performing any lab analysis. A total of 400 swallow holes, rockshelters and caves have been listed during the surveys carried out in recent years on the islands of Guadeloupe (Stouvenot 2003; Lenoble et al. 2011). Eighty-four sites correspond to caves large and deep enough to be penetrated by humans. The criteria as outlined above were used to identify dry caves and distinguish them from wet caves. These last ones have a microclimatic pattern similar to the Morne Rita cave pattern. They are recognized during surveys by the high humidity felt throughout the site, as well as condensation droplets present on the walls, and dripholes on ground. Sixty-seven of the 84 known caves in Guadeloupe were thus categorized, the remaining 17 caves being either sea cave, or cave with many entrances and a microclimatic pattern that doesn't fit to one of the two sites studied in Marie-Galante.

The spatial distribution of caves assigned to a category shows that caves on Guadeloupe are mainly dry cave (89% of categorized sites, Figure 8). Some "wet" caves exist, mainly in the central portions of the islands. Insofar as the caves used by precolumbian people are located near the precolumbian villages and these last ones lie in coastal settings on Guadeloupe (Grouard et al. 2014); this spatial distribution shows that caves the most likely to have been painted and engraved by precolumbian people are dry caves with poor conditions for the preservation of rock art. The Patate rockshelter and the Morne Rita cave, two wet caves, are notable exceptions.

It may be worth noting that other burial caves known in Guadeloupe, namely the Voûte à Pin in La Désirade and the Cadet 2 cave in Marie-Galante, do not contain any petroglyph, but fulfill the above mentioned criteria characterizing site unfavorable to rock art preservation. Like for the cave Blanchard, the absence of petroglyphs in these two sites cannot be considered to be significant. Moreover, these examples and the predominance of dry caves indicate that the hypothesis of a bias by non-preservation of rock art is not restricted to the cave Blanchard, but can be applied to all the Guadeloupe islands.

Implications on Cave Art in the Lesser Antilles

These results raise the question of their relevance to a wider geographical scale, namely all the limestone islands of the Lesser Antilles.

Answering this question by quantifying the cave types according to their microclimate pattern is out of reach, especially because with the exception of Anguilla (McFarlane 1989) and St. Bartholomew (Lenoble et al. 2012), caves on the other Lesser Antilles islands are not accurately described.

However, it is still possible to discuss this issue by noting that the predominance of dry coastal caves on Guadeloupe islands is mainly determined by two factors. The first one is the porous nature of the limestone, due to its young age (Miocene to Pleistocene). This porous nature does not allow the development of neither large karst network nor underground river (Rodet 1987), while this last kind of karst development would favor the occurrence of moist cave as well as caves located in the central portion of islands. The second factor is an island situation where karst dissolution is mainly active in the water table, especially in the mixing zone between fresh and seawater, as described by the model of carbonated island karst (Mylroie and Carew 1990, 2003). Limestone dissolution in this mixing zone produces caves called flank margin caves (Mylroie and Carew 1990, 2003). The predominance of this speleogenesis mode therefore results in caves located near the shore, as shown in Guadeloupe (Lenoble et al. 2009, 2011) and on Mona Island (Frank et al. 1988). It also induces the development of dry caves, since flank margin caves have typically a horizontal development (Mylroie and Carew 1990).

In the Lesser Antilles, the porous nature of limestone and an insular situation are features shared by all the limestone islands. Consequently, the morphological characteristics and the coastal location of the caves are likely to be similar. This is not the case in the Greater Antilles, where a great geological and geographic variety resulted respectively in a diversity of speleogenesis modes (aquifers, underground rivers, etc.), and in varied locations including many inland caves (Fincham 1997; Lace 2012).

These observations suggest that the pattern of dry cave with poor conditions for rock art preservation is relevant for the whole area of the Lesser Antilles. One

INDICE

can then legitimately wonder whether the low number of art caves in the Lesser Antilles compared to the many rock art sites in the Greater Antilles is not biased, mainly resulting from distinct environmental contexts rather than cultural differences of Amerindian societies.

CONCLUSION

This study demonstrates that the low number of rock art caves in Lesser Antilles as well as the occurrence of petroglyphs in humid caves could not result from a cultural choice of Amerindian societies, unlike what is often written (Dubelaar 1995; Petersen et al. 2005; Petitjean Roget 2005). Both characteristics could better relate to a regional context involving a speleogenesis mode and a coastal setting of precolumbian caves which are together unpropitious to engravings preservation. Indeed, a detailed study of two caves in Marie-Galante allowed establishing the causal links between this regional context and the weathering degradation or preservation processes of precolumbian cave art.

The predominance of flank margin caves results in preferential coastal location of sites as well as cave morphology permitting salt air to enter the cave via air currents. This process induces a fast salt weathering of the cave walls, which was estimated to around 1mm per century in the studied cave where this phenomenon was observed. Thus, it is very likely that rock art caves known in Lesser Antilles represent only a small proportion of the original precolumbian petroglyph sites. This result applies to Marie-Galante, but also to all the Guadeloupe Islands and, probably to all the limestone islands of the Lesser Antilles.

ACKNOWLEDGEMENTS

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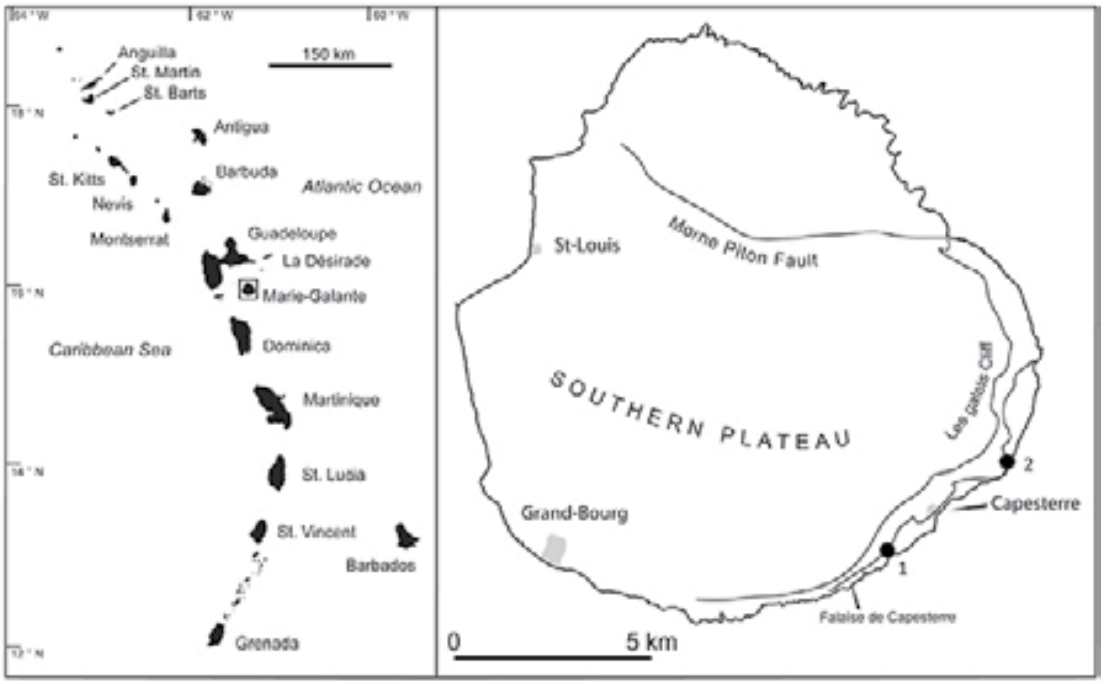

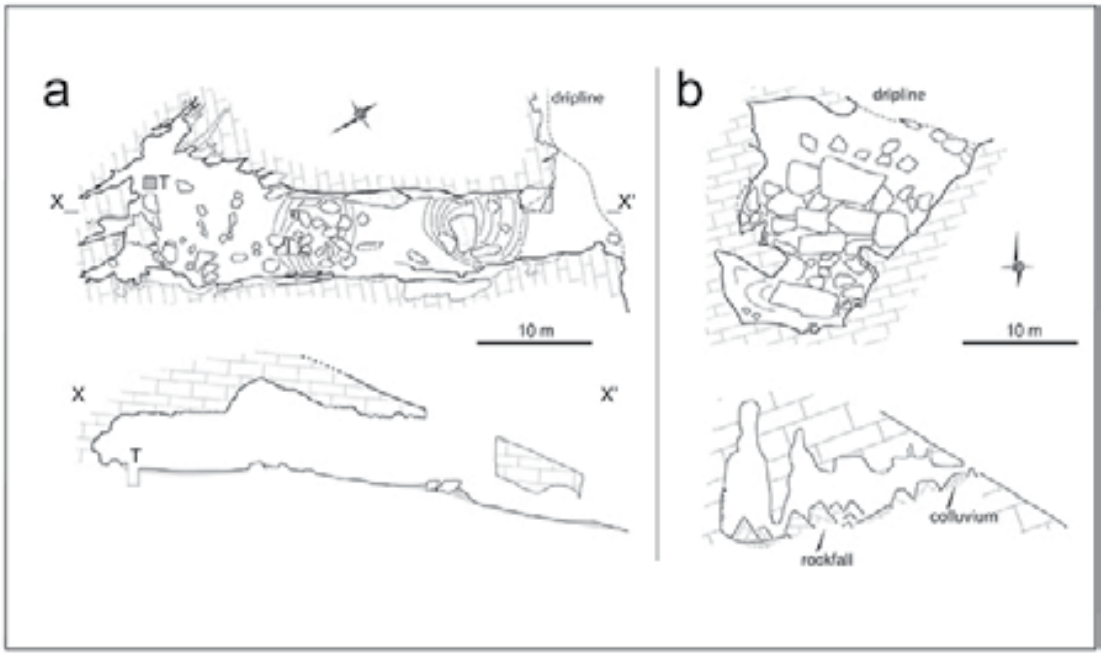

Figure 1: Map of the Marie-Galante Island with the location of caves discussed in the text: 1) Blanchard cave, 2) Morne Rita cave.

Figure 2: topography of caves discussed in the text. A –Blanchard cave (T = test pit location); B- Morne Rita cave. This last cave topography from Rodet (1987) modified.

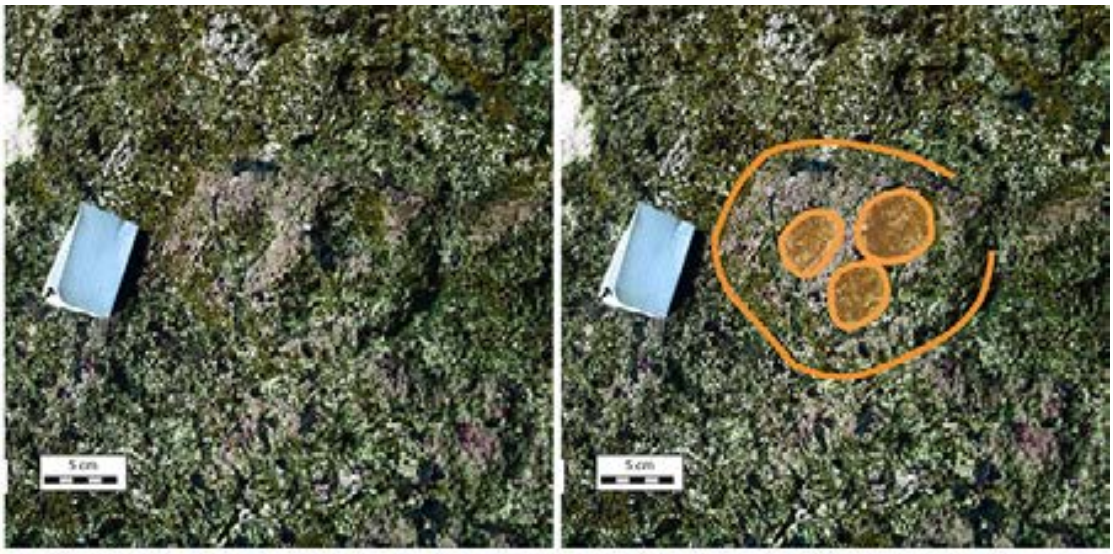

Figure 3: Pareidolia of Blanchard cave.

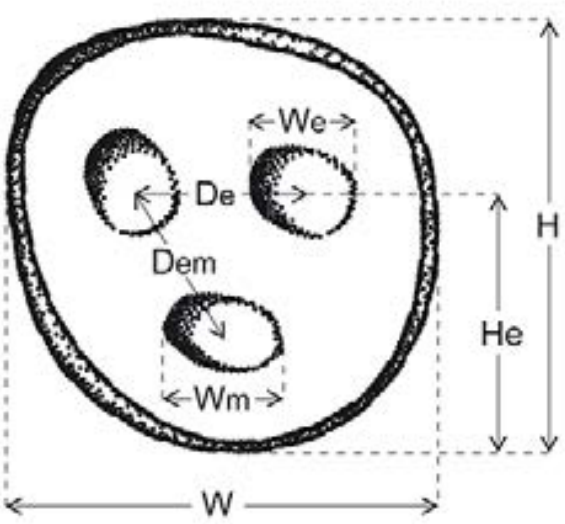

Figure 4: Size index used for comparison between the pareidolia of Blanchard cave and the engravings of Morne Rita cave. W, Face width; We, Eye width; Wm, Mouth width; H, Face height; He, Eyes Height; De, Inter-eyes distance; Dem, Mouth-Eye distance.

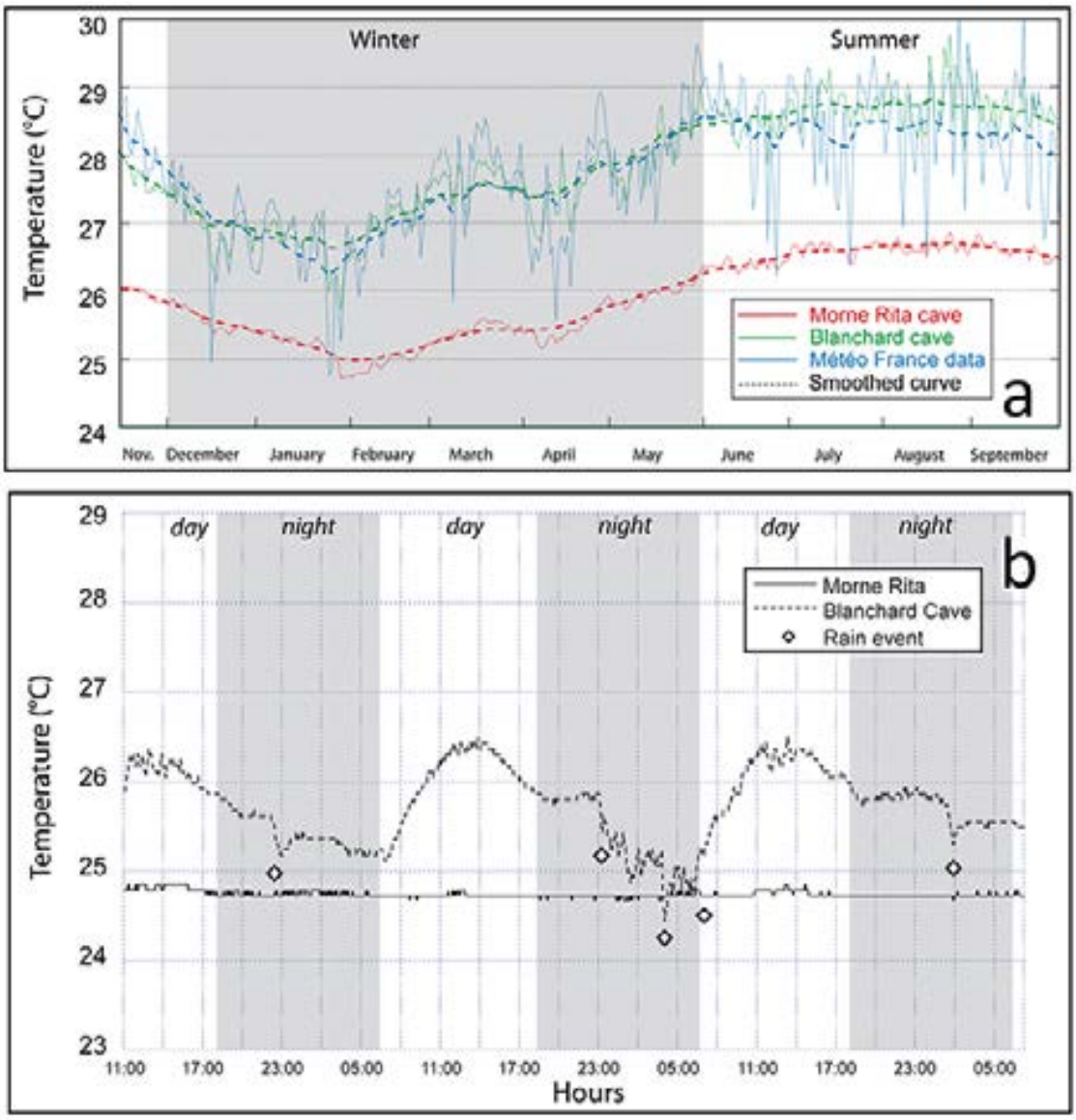

Figure 5: temperature and hygrometry variation recorded in both caves. A -Mean daily temperature from the back of both caves and Météo-France data between November 2009 and September 2010; B - High-resolution temperature record correlated to observed rainfalls (Feb. 21-24, 2011).

INDICE

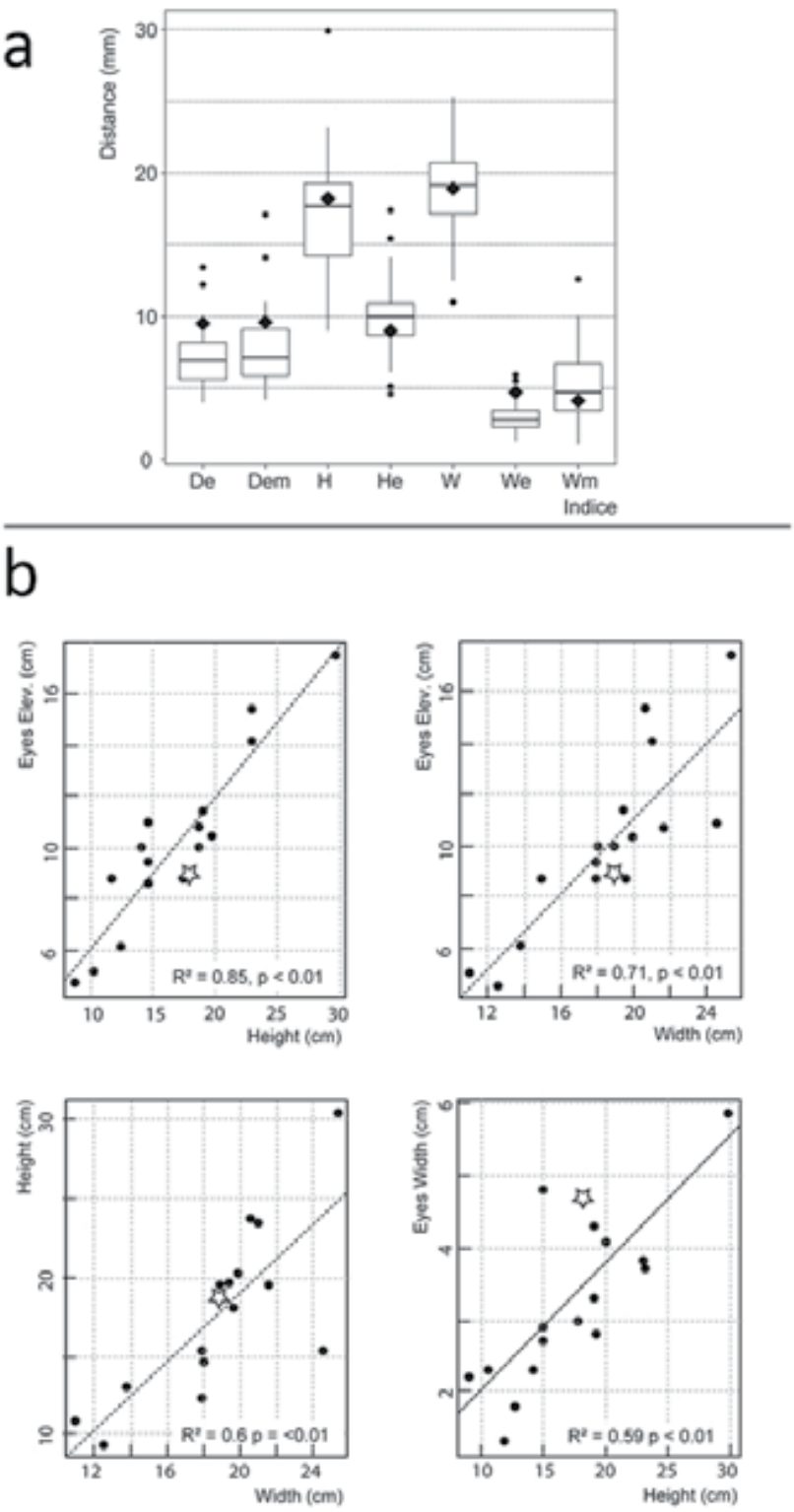

Figure 6: morphometric comparison between the pareidolia of the Blanchard cave and the Morne Rita engravings. A- Boxplot of the morphological indices based on the Morne Rita engravings (Blanchard cave pareidolia is figured by a black diamond). B – Examples of scatterplots for different set of indices (the Blanchard cave pareidolia is shown by a white star).

INDICE

Figure 7: Sketch of the causal relation between microclimatic and mineralogical parameters involved in the pattern of dry versus wet cave and their influence on engraving preservation. A, Blanchard cave; B, Morne Rita cave.

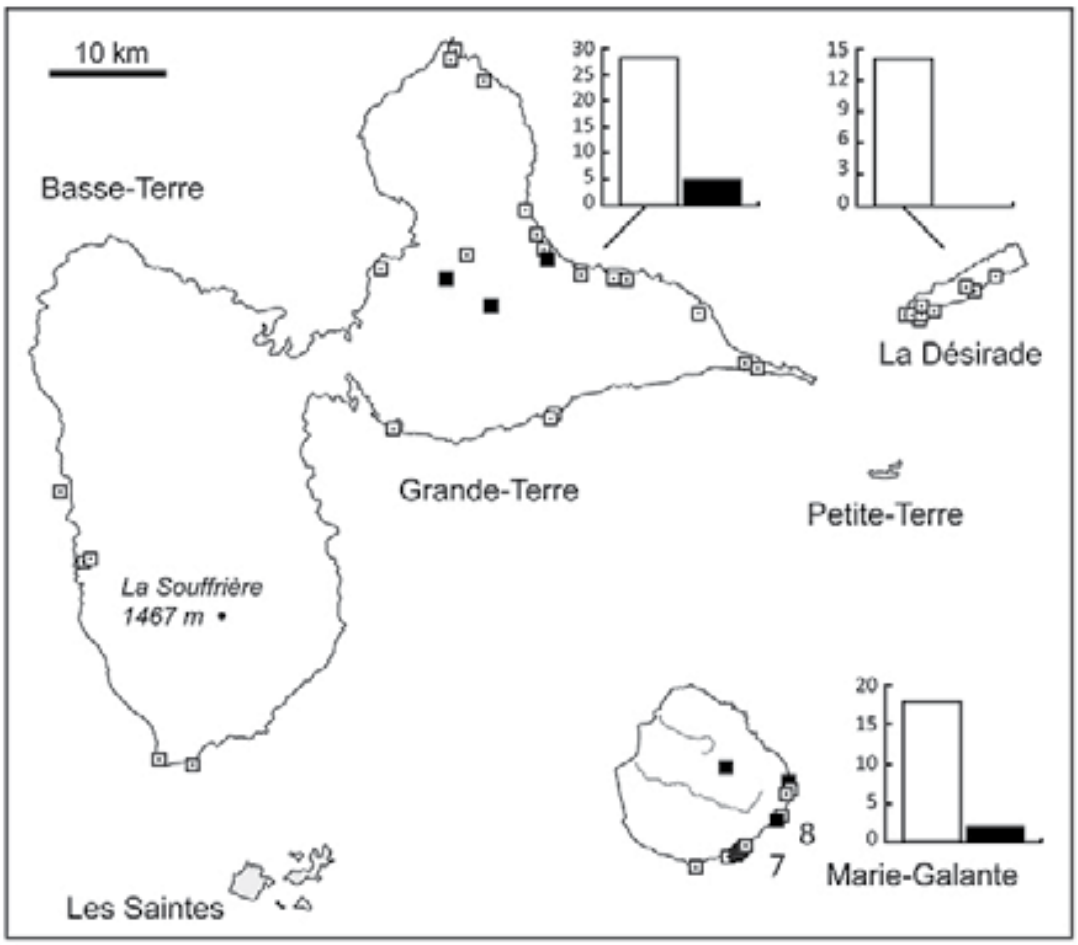

Figure 8: Map of the Guadeloupe archipelago with distribution of dry (white dot) and wet cave (black dot) and proportion of cave type for each main island.

INDICE